Global implications of the EU battery regulation

A much-needed law may have unintended global consequences

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Transport electrification is a key element of decarbonization strategies, thus the design, production, manufacture, use, and disposal of lithium-ion batteries (LIBs) is taking center stage. The environmental, economic, and social consequences of the battery life cycle are high on political agendas, due to exponential growth in metals extraction; the climate impacts of battery production; uncertainties in battery end-of-life (EoL) safety, recyclability, and environmental consequences (1) (Figure S1-3, SM). The European Union (EU) has proposed a new Battery Regulation (2) that intends to ensure sustainability for batteries placed on the EU market (see figure), developing a robust European battery industry and value chain. The Regulation is very much needed but as we discuss below it will have global implications, with perhaps some unintended consequences. If left unaddressed, the Regulation, at worst, could hamper climate change mitigation targets and fall short of its intentions to promote a circular economy and establish a socially acceptable raw material supply chain.

The proposed Regulation will replace the 2006 EU Battery Directive (3), which addressed the challenges of its time, controlling a range of hazardous substances including lead, cadmium, and mercury present in portable and industrial batteries. However, the Directive was designed in an era with different supply chain concerns, and before the exponential growth of large-format LIBs used in EVs. The proposed Regulation addresses this era's challenges, stipulating labelling and information provisions, setting out supply chain due diligence requirements, and

enforcing the use of recycled materials for batteries over 2 kWh, most of which are used in EVs. Historical data shows an almost ten-fold increase of LIBs placed on global markets in the last 10 years (Figure S4 and S5, SM) and a similar growth rate is expected during this decade (Figure S1). Therefore, it is imperative to address the global climate change challenge and battery issues in tandem (4-6). **While the Regulation only applies directly to the European market, indirect effects will be felt globally given the international nature of LIB supply and value chains.**

Despite being the second largest market for EVs in the world, Europe does not dominate LIB supply chains, instead relying on global markets for raw material extraction, refining, and battery manufacturing (7). From the moment the Regulation enters into force, potentially in 2023, producers and importers of batteries will need to comply with the Regulation to sell or use batteries on the European market. EVs not only help achieve global carbon reduction targets; they also serve as a driver of growth and job creation in Europe (8), the United States (9), China (4) and a few other markets such as South Korea and Japan. As such, the Regulation must balance concerns about environmental stewardship with regional interests in economic competitiveness.

The new Regulation (2) brings European legislation up-to-date, anticipating near term developments [in 2035] and building upon the previous Directive (Figure S6, SM). **The Regulation comes with explicit aims to provide incentives to invest in production capacity for sustainable batteries by creating a level playing field. There is a clear sentiment to have a sustainable battery value chain. Europe will seek to obtain a global competitive advantage and build barriers to entry.**

We distill the Regulation's 79 Articles into four key elements that we see as core to improve the sustainability of LIBs. First, the Regulation intends to increase transparency and traceability across the battery life cycle (e.g., Articles, 10, 47 and 65 in Figure), mandating 3rd party due diligence of the supply and value chains for batteries >2 kWh (e.g. Articles 8, 39 and 72). Second, it addresses

climate impact throughout the battery life cycle (e.g., Article 7) by mandating carbon footprint declaration and later establishing maximum thresholds; together, these first two elements seek to ensure the quality and availability of the underlying data needed to guide environmental responsibility and track compliance by industrial players. Third, concrete actions to promote the circularity of critical materials are emphasized (e.g., Articles 47, 55 and 57), targeting increased collection and recycling efficiency; improving recovery rates for lithium, cobalt, and nickel; as well as mandating the use of recycled materials in new batteries (e.g., Articles 8, 55 and 59). Fourth, requirements for longevity and performance management are proposed, including access for waste processors to the battery management system (BMS) which monitors different characteristics and controlling functions for safe operation and optimal use. The BMS also verifies the state of health of the battery in real time and can determine the potential for the battery to be reused or repurposed before being recycled. (e.g., Articles 51, 59 and 65 in Figure). These last two elements provide a foundation for EU efforts to establish circularity as an economic opportunity aligned with its long-term sustainability objectives.

A Global system

In addition to the proposed Regulation, the European Commission (EC) is supporting battery developments through a range of initiatives such as the creation of the European Battery Alliance and financial aid packages to support research and innovation along the entire battery value chain (4). Under the label "*open strategic autonomy*" the union seeks to combine free trade with an ability to manage its own destiny in key sectors. The LIB market is dominated by Chinese companies, occupying more than two-thirds of the supply chain (7) including resources outside of China. The United States market has, through Tesla, been on the forefront of large-scale battery production but has, like Europe, failed to secure key elements of the supply and value chain such as refining, production, or recycling of battery materials (Figure S7). The regulatory environment in each market

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will play a key role as electrification of the transportation sector intensifies.

In China, the LIB market has profited from the rapid growth in the EV sector, fueled by strong government support in the form of both subsidies and investment stimulus. A whole-of-government approach has provided clear strategic guidance; and the Interim Measures for the Administration of the Recycling and Utilization of Power Batteries for New Energy Vehicles from 2018 reflect a number of the themes found in the EU Regulation (10). These included minimum standards for the reclassification of batteries for reuse applications, the recycling efficiency of plants treating batteries at the EoL, and requirements for product labelling to qualify for subsidies. In 2019, these regulations were tightened to levels stricter than the EU Regulation plans to enforce a decade from now (2). In December 2020 China's State Council issued "Energy in China's New Era", a blueprint for energy sector development through 2030. It includes guidance on the development of battery supply chains, including recycling to support energy efficiency, and provisions for reducing the carbon intensity of electricity used to power EVs (9).

In the United States, electrification of transportation, and the supply of critical materials that enable it, has been declared a top priority of the Biden Administration. This is reflected in an investment proposal of up to \$174 billion in EV programs focused on re-establishing primary metals refining and manufacturing in the United States, and creating new recycling capabilities as part of materials criticality efforts. In the policy arena however, the US lags both the EU and China in mandating Extended Producers Responsibility (EPR) or promoting circular economy principles other than basic legislation to keep batteries classified as hazardous waste out of landfills and incinerators.

Challenges to overcome

Current battery legislation in all three major markets, China, the EU and the United States, is geared towards the protection of local environment and human health. However, the scopes of China's and EU's policies include measures which, directly or indirectly, give companies that manage to comply important competitive advantages both domestically and globally, the mandatory recovery rates for recyclers being a standout example (Table S1). An important distinction arises however in the manner by which Chinese and EU regulations impact the global value chain. Compared to the EU, China has more direct leverage due to its

dominance in materials refining, battery material and cell production, and a much more mature recycling infrastructure. While tougher requirements for placing batteries on the European market force players around the world, including the EU, to comply, the domestic requirements on the Chinese companies have already helped them do that.

This imbalance between new and mature markets is one of several factors that can lead to unintended consequences, not just in Europe but globally when a nascent market is shaped by regulation. **We discuss here consequences such as distorted innovation, material leakage, and investment slowdown.**

Distorted innovation

The LIB industry is experiencing both rapid growth and innovation. Together, these dynamics create uncertainty around how the markets will evolve, making it difficult for industry to properly invest for future growth. In this context, regulations offer considerable impetus by creating stable frameworks under which market players operate. Overly stringent regulations on batteries risk imposing compliance costs that hinder competitiveness, leading to reduced innovation and lower EV adoption rates. Few, if any, other technological products appear to be presently regulated in quite the same way – with manufacturers needing to provide details on product life cycle, material sourcing, third-party audit, and recycled content. This means that batteries, the product at the core of transport decarbonization, may in some respects face tougher requirements than the incumbent industry serving the internal combustion engine vehicle market. Even if stricter emission standards are underway, there are no proposals to provide the same value chain transparency.

The new regulation also means that European EV manufacturers will be more constrained in their options to source batteries than manufacturers in the less regulated United States but also in a strongly regulated China as their share of the LIB market is simply so much bigger and their players much more mature. The fact that smaller producers are not exempted from the many potentially burdensome requirements presents a considerable risk that innovation in alternative transportation areas and technological niches such as micro-mobility may be disadvantaged.

A second mechanism for distorted innovation involves situations where regulatory guidance lags the technical realities in the market. In an extreme case, specific regulatory targets might become obsolete even be-

fore they enter into force due to the introduction of new chemistries or battery designs. A second case concerns unexpected "work arounds". Rather than direct compliance on specific materials, producers might opt for raw material substitutions; such decisions upstream in the value chain could unintentionally weaken future markets for recyclers expecting different levels of material availability. In addition, manufacturers might simply incorporate the threshold of 2 kWh as a design parameter to avoid the heavy burden of supply chain due diligence and the use of recycled content, which would make the Regulation ineffective. A third case of distorted innovation is that the requirements on recycled content could hamper the pace of the roll-out of new technologies as well as higher ambitions for the overall growth of the LIB market. This could be particularly relevant for individual manufacturers as the availability of recyclable materials effectively establishes a limit of the amount of certain materials that can be used in the batteries. All three cases reinforce the importance of continual monitoring and adjustment of regulations to ensure that outcomes remain aligned with both their environmental stewardship and economic goals. This importance has been addressed in work preceding the Regulation which motivated the use of "secondary legislation" for specific measures, including recycled content, which will be adaptable over time. However, there is a trade-off between adaptability and stability, which is one of the intentions of the regulation.

Material leakage and investment slowdown

One objective of the Regulation is to responsibly secure material supply chains for Europe's EV industry. Recycling is here a core activity, with recycled content and recovery targets as main measures. However, the Regulation neither requires recycled material to be sourced in Europe nor does it restrict the source of recyclables to EoL batteries. With considerable experience in battery material production, including the use of recycled materials from both EoL batteries and production scrap, several companies in markets like China and South Korea are at least as well, and many times better positioned to meet EU requirements on recycling than European recycling companies. With China's and South Korea's dominance in battery production, these companies also have better access to feedstock of recyclables which already has provided many of the companies with economies of scale and thus a competitive advantage in sourcing recyclables from both

Asia and Europe. This extends to both Asian battery material producers, which are the users of the recycled materials, as well as battery manufacturers with close access to these materials. The net effect of this dynamic could be a higher barrier to entry for European material producers, and ultimately battery manufacturers, in their own market. This issue has been raised by battery manufacturers in stakeholder consultations both before and after the adoption of the Regulation.

This potential outflow of recyclable materials comes on top of the fact that battery-containing products, as well as the batteries themselves, usually cascade through multiple owners and are traded on international markets. EoL batteries still have value and are often exported for reuse and refurbishment, or recycling (12). This outflow makes it more difficult for recyclers in Europe to reach the necessary economies of scale, making them less competitive and less attractive to invest in.

The Regulation's clarification of producer responsibility for repurposed batteries, as well as its waste status, and the mandated access to BMS data might help keep batteries in the EU, facilitating the manufacturing of new battery products which ultimately can reach end of life in Europe. However, it also provides a route for traders to declare the used battery "a resource or product" which facilitates its export, adding to the leakage of recyclable materials. Access to EoL batteries and recyclable materials is primarily a concern for the companies involved in the end-of-life value chain. However, with requirements on recycled content in the batteries this dependency extends to the entire industry including the manufacturing of electric vehicles.

Conclusions

The EU Battery Regulation has admirable intentions – from spurring the growth of domestic industries, to environmental protection at local and global scales, to achieving a truly circular economy. All these goals are intertwined, and one could reasonably argue that they need a unified policy. However, each measure within the policy will have both intended and unintended consequences. The development of largely uncoordinated regional and domestic policies across globally important consumption and production regions make the consequences of the proposed EU Regulation even harder to predict. Although unintended consequences might first impact the EU, they will also be felt by manufacturers, recyclers and

other actors across the world. Ultimately, disruptions in the European battery value chain might limit automotive makers' ability to produce EVs at the scale that is required by 2030 when several countries have placed a ban on the sale of new internal combustion engine vehicles.

Efforts to disentangle the goals of different measures and instruments, and better understand the effects on global supply and value chains, may be made more predictable and powerful if addressed by the global community in coordinated fashion. For example, shifting to open BMS architectures (viz., battery passports, a digital representation of battery environmental, social, governance and life cycle specific information-article 65) represents a major departure from existing business models where manufacturers maintain tight control over the data generated. It is unknown if and how locally acquired battery data will be shared across global value chains. What is likely is that in a unified global market, the dominant market's standard will drive compliance.

Having clear and stringent global standards in areas where regulations are limited in scope such as recycling, circularity, and cascaded use for batteries could provide EU firms with a first mover advantage in achieving product differentiation in battery markets. Perhaps this can form a non-tariff barrier to cheaper imported products, affording some protection to European battery-makers. Over the longer term, a more robust global supply chain with many players across raw materials, EoL components, and recycling value chains is good for the environment overall – and will benefit innovative players regardless their origin.

Since standards on battery supply and value chains are uneven around the world, establishing global standards that all countries adhere to could help ensure a level (and sustainable) playing field, and facilitate coordination on these global challenges and solutions. The EU Regulation is among the most advanced environmental standards influencing environmental stewardship and sustainability. While embedded resistance from market players alongside the challenges inherent in international negotiations present formidable hurdles to the establishment of global standards, the EU's share of the EV market provides it with considerable leverage to set standards that might be accepted on a *de facto* basis.

In similar fashion there should be an ambition to align other product areas with the

same standards, ensuring the battery industry is not disadvantaged in relation to other energy storage and power technologies.

In summary, the EU Regulation places the EU on the forefront of regulating battery markets, providing much needed policies and legislation that address environmental and social issues. However, these policies need to contemplate the unintended consequences, both in the near and distant future.

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Supplementary Materials
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Figure. A Circular Economy for Electric Vehicle Batteries, key Articles from the proposed EU Battery Regulation

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